

What is Claimed is:

## 1. A swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end

5 and at least first and second outer annular grooves formed on the outer surface  
coaxial with the central axis;

a tubular female member having an inner annular recess, an  
annular shoulder formed at an inner end of the recess and at least first and  
second inner annular grooves formed on the recess coaxial with the central axis;

10 wherein the outer surface of the male member is adapted to be  
received in the recess of the female member such that the first end is disposed  
proximate the shoulder and each outer groove is aligned with a corresponding  
inner groove to thereby define at least first and second annular races;

15 a plurality of balls disposed in each race to secure said male and  
female members together and to facilitate relative rotation of the male and female  
members about the central axis;

wherein the radius of each race as measured from the central axis  
is greater than the radius of each adjacent race closer to the first end of the male  
member; and

20 wherein the number of balls in each race is <sup>just</sup> one more than the  
number of balls in each adjacent race closer to the first end.

2. The swivel joint of claim 1, further comprising means for sealing  
between the male and female members.

3. The swivel joint of claim 2, wherein the sealing means comprises an annular seal disposed between the first end of the male member and the shoulder of the female member.

4. The swivel joint of claim 3, wherein the annular seal is comprised of an elastomer.

5. The swivel joint of claim 2, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the male and female members.

6. The swivel joint of claim 1:

wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the balls.

7. A swivel joint comprising:

a central axis;

a tubular male member having an outer annular surface, a first end and at least first and second outer annular grooves formed on the outer surface coaxial with the central axis;

a tubular female member having an inner annular recess, an annular shoulder formed at an inner end of the recess and at least first and

second inner annular grooves formed on the recess coaxial with the central axis;

wherein the outer surface of the male member is adapted to be received in the recess of the female member such that the first end is disposed proximate the shoulder and each outer groove is aligned with a corresponding inner groove to thereby define at least first and second annular races;

a plurality of balls disposed in each race to secure said male and female members together and to facilitate relative rotation of the male and female members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first end of the male member by an amount sufficient to enable each race to accommodate <sup>just</sup> one more ball than is disposed in the adjacent race.

8. The swivel joint of claim 7, further comprising means for sealing between the male and female members.

9. The swivel joint of claim 8, wherein the sealing means comprises an annular seal disposed between the first end of the male member and the shoulder of the female member.

10. The swivel joint of claim 9, wherein the annular seal is comprised of an elastomer.

11. The swivel joint of claim 8, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the male and female members.

12. The swivel joint of claim 7:

wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

wherein the radius of the first and second segments is substantially the same as the radius of the balls.

13. A swivel joint comprising:

a central axis;

a pair of tubular members each having a first end and a plurality of outer annular grooves formed coaxial with the central axis;

a collar member comprising a pair of inner cylindrical recesses each having a plurality of inner annular grooves formed coaxial with the central axis;

wherein each tubular member is adapted to be received in a corresponding recess of the collar member such that the first ends are proximate one another and each outer groove is aligned with a corresponding inner groove to thereby define a plurality of annular races;

a plurality of balls disposed in each race to secure said tubular members in said collar and to facilitate relative rotation of the tubular members about the central axis;

wherein the radius of each race as measured from the central axis is greater than the radius of each adjacent race closer to the first ends of the

tubular members; and

wherein the number of balls in each race is <sup>just</sup> one more than the number of balls in each adjacent race closer to the first ends of the tubular members.

5           14.    The swivel joint of claim 13, further comprising means for sealing between each tubular member and the collar member.

15.    The swivel joint of claim 14, wherein the sealing means comprises an annular seal disposed between the first ends of the tubular members.

10           16.    The swivel joint of claim 15, wherein the annular seal is comprised of an elastomer.

17.    The swivel joint of claim 14, wherein the sealing means comprises a straight bore seal which is disposed in a seal pocket formed in adjacent portions of the first ends of the tubular members.

15           18.    The swivel joint of claim 13:  
wherein the cross section of at least each outer groove or each inner groove comprises first and second arcuate segments each having a distinct centerpoint and substantially the same radius;

wherein the centerpoint of the first segment is offset from the centerpoint of the second segment in a direction parallel to the central axis; and

20           wherein the radius of the first and second segments is substantially the same as the radius of the balls.